

# **Capturing Business Complexity with Agent-Based Modeling and Simulation: Useful, Usable, and Used Techniques**

**An Argonne National Laboratory,  
University of Chicago, and  
Santa Fe Institute Course  
with a Focus on Business Applications**

## **Course Schedule**

### **Session I: Agent-Based Modeling and Simulation Concepts**

<b>Day 1: Monday</b>		
<b>Start</b>	<b>End</b>	<b>Section</b>
8:30 AM	8:45 AM	Welcome to Argonne National Laboratory <i>Harvey Drucker, Argonne National Laboratory</i> Harvey Drucker will welcome the participants to the Laboratory.
8:45 AM	9:00 AM	Welcome to Argonne's Decision and Information Sciences Division <i>Thomas Wolsko, Argonne National Laboratory</i> The Director of Argonne National Laboratory's Decision and Information Sciences Division (DIS) will discuss the goals of the course and how DIS' focus on developing useful, usable, and used software has shaped these goals. The short-term goals of the course include imparting ABMS knowledge and skills that are useful in a business setting. The long-term goals of the course include building a vibrant business-oriented ABMS community.

9:00 AM	9:15 AM	<p>Welcome to the Course</p> <p><i>Susan Ballati, Santa Fe Institute</i></p> <p>The Santa Fe Institute Vice President for Academic Affairs will discuss the importance and utility of capturing business complexity with agent-based modeling and simulation (ABMS).</p>
9:15 AM	10:00 AM	<p>Course Overview</p> <p><i>Michael North, Argonne National Laboratory</i></p> <p>ABMS is an exciting new approach to capturing business complexity. Developing the knowledge and skills necessary to apply ABMS to business questions requires focused learning. An overview of the focused learning approach offered by the course will be provided.</p>
10:00 AM	10:30 AM	<p>Break</p> <p>Refreshments will be provided.</p>
10:30 AM	Noon	<p>ABMS: Useful, Usable, and Used</p> <p><i>Charles Macal, Argonne National Laboratory</i></p> <p>How ABMS can be useful to businesses, how it can be made usable by businesses, and how it could be used by businesses will be discussed. The discussion will be illustrated with specific ABMS problem-solving examples from the energy and healthcare sectors.</p>
Noon	1:30 PM	<p>Lunch Work Session</p> <p>Lunch will be provided. During lunch participants will be asked to begin considering how ABMS might be applicable to their businesses.</p>
1:30 PM	2:00 PM	<p>ABMS Applications Discussion Session</p> <p><i>Richard Cirillo, Argonne National Laboratory</i></p> <p>Participants will discuss their questions about and thoughts on how ABMS might be applied to address issues of interest in their businesses.</p>
2:00 PM	3:30 PM	<p>ABMS Architectural Design</p> <p><i>Michael North, Argonne National Laboratory</i></p> <p>ABMS models consist of a set of agents and a framework for their interaction. Tools such as Swarm and Repast provide a wide range of capabilities that directly support the development of appropriate agents and their surrounding environments. Marshalling these capabilities to match the requirements of a given ABMS project requires effective model-specific architectural designs. Approaches to developing such architectural designs will be discussed in detail.</p>
3:30 PM	4:00 PM	<p>Break</p> <p>Refreshments will be provided.</p>
4:00 PM	5:30 PM	<p>ABMS Agent Design</p> <p><i>David Sallach, University of Chicago</i></p> <p>Agents and their rules of action form the core of ABMS. Designing agents in the context of a specific architecture sets the stage for ABMS implementation. A variety of approaches to designing agents will be discussed in detail.</p>

<b>Day 2: Tuesday</b>		
<b>Start</b>	<b>End</b>	<b>Section</b>
8:30 AM	10:00 AM	<b>ABMS Prototyping</b> <i>Michael North, Argonne National Laboratory</i> Prototyping is a powerful way to identify important modeling issues and to discover unexpected interactions early in the ABMS development process. It can also provide initial benchmarks for preliminary ABMS validation. Prototyping approaches and concepts will be discussed. The practical uses of live simulations and spreadsheets as ABMS prototyping tools and an example of a live simulation developed to explore the central features of an energy market will also be discussed.
10:00 AM	10:30 AM	<b>Break</b> Refreshments will be provided.
10:30 AM	Noon	<b>ABMS Verification and Validation</b> <i>Michael North, Argonne National Laboratory</i> <i>Michelle Girvan, Santa Fe Institute</i> Verification approaches are used to determine how closely an implemented ABMS matches its intended design. Validation approaches are used to determine how well an ABMS reproduces the real situations being modeled. ABMS verification and validation will be discussed in detail.
Noon	1:30 PM	<b>Lunch Work Session</b> Lunch will be provided. During lunch participants will be asked to begin designing a conceptual ABMS architecture, agents, and an agent environment to address issues of interest in each of their businesses.
1:30 PM	2:00 PM	<b>ABMS Applications Discussion Session</b> <i>Richard Cirillo, Argonne National Laboratory</i> Participants will discuss the conceptual ABMS architectures, the agents, and the agent environments that they developed to address issues of interest in each of their businesses.
2:00 PM	3:00 PM	<b>Data Collection and Cleaning</b> <i>John Padgett, University of Chicago and Santa Fe Institute</i> The collection of data will be discussed. Approaches to cleaning data during and after collection will also be discussed.
3:00 PM	3:30 PM	<b>Break</b> Refreshments will be provided.
3:30 PM	5:00 PM	<b>Understanding ABMS Results</b> <i>Charles Macal, Argonne National Laboratory</i> Well-constructed ABMS models often generate complex but extremely useful information. Approaches to understanding ABMS results will be discussed in detail using a supply chain example.
5:00 PM	5:30 PM	<b>Presenting ABMS Results</b> <i>Richard Cirillo, Argonne National Laboratory</i> Most insights gained from ABMS must be effectively communicated to others to be useful. Practical approaches to presenting ABMS results will be discussed using an energy market example.

<b>Day 3: Wednesday (Morning Sections)</b>		
<b>Start</b>	<b>End</b>	<b>Section</b>
8:30 AM	9:15 AM	ABMS Example: Energy Markets <i>Thomas Veselka, Argonne National Laboratory</i> An example energy market ABMS will be discussed.
9:15 AM	10:00 AM	ABMS Example: Successful Real-world Applications of Agent-Based Modeling <i>Eric Bonabeau, Icosystem Corporation</i> An example business ABMS will be discussed.
10:00 AM	10:30 AM	Break Refreshments will be provided.
10:30 AM	11:15 AM	ABMS Example: Retail Simulation and the Advent of Agent-Based Methods <i>Mark Kimura, MPSI Incorporated</i> An example consumer market ABMS will be discussed.
11:15 AM	Noon	ABMS Example: Law <i>Randal Picker, University of Chicago</i> Example applications of ABMS to the law will be discussed.
Noon	1:30 PM	Lunchtime Lecture: The Promise of Business ABMS <i>John Casti, Technical University of Vienna</i> The promise of business-oriented ABMS will be discussed. Lunch will be provided.

## Session II: ABMS Software Development

The course schedule for Session II will be as follows.

Day 3: Wednesday (Afternoon Sections)		
Start	End	Section
1:30 PM	2:30 PM	Agents as Objects <i>Michael North, Argonne National Laboratory</i> ABMS agents can be usefully thought of as “self-directed” objects. The two most widely used ABMS tools, Repast and Swarm, are both object-oriented. The general principles of OOP and the differences between OOP and standard structured programming will be discussed in the context of ABMS. The relationship between ABMS agents and OOP objects will be discussed in detail.
2:30 PM	3:30 PM	A Supply Chain Example <i>Charles Macal, Argonne National Laboratory</i> Complex supply chain operation is a key feature of modern business. A supply chain example that will later be captured using ABMS will be introduced.
3:30 PM	4:00 PM	Break Refreshments will be provided.
4:00 PM	5:30 PM	Capturing the Supply Chain Example with Mathematica <i>Charles Macal, Argonne National Laboratory</i> A Mathematica ABMS approach to capturing the previously introduced supply chain example will be discussed using UML diagrams and Mathematica notebooks.

Day 4: Thursday		
Start	End	Section
8:30 AM	10:00 AM	Capturing the Supply Chain Example with Repast: Basic Features <i>Michael North, Argonne National Laboratory</i> <i>Charles Macal, Argonne National Laboratory</i> <i>Nick Collier, University of Chicago/Argonne National Laboratory/Panta Rei Corporation</i> A Repast ABMS approach to modeling the previously introduced supply chain example will be discussed. A hands-on approach will be used wherein the instructor will describe each Repast ABMS concept and then the participants will immediately apply the concept to solidify their understanding.
10:00 AM	10:30 AM	Break Refreshments will be provided.

10:30 AM	Noon	<p>Capturing the Supply Chain Example with Repast: Input Preparation and Output Visualization</p> <p><i>Michael North, Argonne National Laboratory</i>  <i>Charles Macal, Argonne National Laboratory</i>  <i>Nick Collier, University of Chicago/Argonne National Laboratory</i>  <i>/Panta Rei Corporation</i></p> <p>Discussion of the previously introduced Repast supply chain model will continue including coverage of input preparation and output visualization. A hands-on “learning by doing” approach will be used.</p>
Noon	1:30 PM	<p>Lunch</p> <p>Lunch will be provided.</p>
1:30 PM	3:30 PM	<p>Capturing the Supply Chain Example with Repast: Agent Adaptation and Learning</p> <p><i>Michael North, Argonne National Laboratory</i>  <i>Charles Macal, Argonne National Laboratory</i>  <i>Nick Collier, University of Chicago/Argonne National Laboratory</i>  <i>/Panta Rei Corporation</i></p> <p>Discussion of the previously introduced Repast supply chain model will continue including coverage of agent adaptation and learning. A hands-on “learning by doing” approach will be used.</p>
3:30 PM	4:00 PM	<p>Break</p> <p>Refreshments will be provided.</p>
4:00 PM	5:30 PM	<p>Capturing the Supply Chain Example with Repast: Advanced Features</p> <p><i>Michael North, Argonne National Laboratory</i>  <i>Charles Macal, Argonne National Laboratory</i>  <i>Nick Collier, University of Chicago/Argonne National Laboratory</i>  <i>/Panta Rei Corporation</i></p> <p>Discussion of the previously introduced Repast supply chain model will continue including coverage of Repast’s advanced modeling features. A hands-on “learning by doing” approach will be used.</p>
5:30 PM	8:30 PM	<p>Optional Repast Open Laboratory</p> <p>An optional opportunity to continuing working with Repast will be provided. Several instructors will be available to assist participants and answer their questions.</p>

Day 5: Friday		
Start	End	Focus
8:30 AM	10:00 AM	<p>Capturing the Supply Chain Example with Swarm: Basic Features</p> <p><i>Michael North, Argonne National Laboratory</i>  <i>Charles Macal, Argonne National Laboratory</i>  <i>Roger Burkhart, Deere &amp; Company</i></p> <p>A Swarm ABMS approach to modeling the previously introduced supply chain example will be discussed. A hands-on approach will be used wherein the instructor will describe each Swarm ABMS concept and then the participants will immediately apply the concept to solidify their understanding.</p>

10:00 AM	10:30 AM	Break Refreshments will be provided.
10:30 AM	Noon	Capturing the Supply Chain Example with Swarm: Input Preparation and Output Visualization <i>Michael North, Argonne National Laboratory</i> <i>Charles Macal, Argonne National Laboratory</i> <i>Roger Burkhart, Deere &amp; Company</i> Discussion of the previously introduced Swarm supply chain model will continue including coverage of input preparation and output visualization. A hands-on “learning by doing” approach will be used.
Noon	1:30 PM	Lunch Lunch will be provided.
1:30 PM	3:00 PM	Capturing the Supply Chain Example with Swarm: Agent Adaptation and Learning <i>Michael North, Argonne National Laboratory</i> <i>Charles Macal, Argonne National Laboratory</i> <i>Roger Burkhart, Deere &amp; Company</i> Discussion of the previously introduced Swarm supply chain model will continue including coverage of agent adaptation and learning. A hands-on “learning by doing” approach will be used.
3:00 PM	3:30 PM	Break Refreshments will be provided.
3:30 PM	4:30 PM	Capturing the Supply Chain Example with Swarm: Advanced Features <i>Michael North, Argonne National Laboratory</i> <i>Charles Macal, Argonne National Laboratory</i> <i>Roger Burkhart, Deere &amp; Company</i> Discussion of the previously introduced Swarm supply chain model will continue including coverage of Swarm’s advanced modeling features. A hands-on “learning by doing” approach will be used.
4:30 PM	5:30 PM	The Future of ABMS <i>David Sallach, University of Chicago</i> In recent times, a wide range of transdisciplinary techniques have coalesced into what is now known as ABMS. However, ABMS is still an embryonic and continuously evolving art and science. Areas of ABMS that are likely to change will be highlighted and exciting directions for future growth will be discussed.
5:30 PM	8:30 PM	Optional Swarm and Repast Open Laboratory An optional opportunity to continuing working with Swarm and Repast will be provided. Several instructors will be available to assist participants and answer their questions.